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(54) **METHODS AND SYSTEMS FOR INDICATING AND DETERMINING FUEL PROPERTIES**

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7,917,298 B1 *	3/2011	Scher et al. ....	702/19
8,158,432 B2 *	4/2012	Grof et al. ....	436/56
2004/0248307 A1 *	12/2004	Grof et al. ....	436/56
2010/0121551 A1 *	5/2010	Boss et al. ....	701/99
2010/0208243 A1 *	8/2010	Suzuki et al. ....	356/128
2010/0258718 A1 *	10/2010	Welle ....	250/302
2010/0305885 A1 *	12/2010	Ganapathy et al. ....	702/55
2011/0182805 A1 *	7/2011	DeSimone et al. ....	424/1.11
2011/0229983 A1 *	9/2011	Wilkinson et al. ....	436/501
2012/0330532 A1 *	12/2012	Matsuura et al. ....	701/103
2013/0179090 A1 *	7/2013	Conroy et al. ....	702/25
2013/0267034 A1 *	10/2013	Izumiya et al. ....	436/164
2013/0268209 A1 *	10/2013	Tashima et al. ....	702/25

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#### OTHER PUBLICATIONS

Unknown, "InkSure's Taggant Technology for Fuel Security and Energy Protection", Aug. 15, 2011, 1 page, Inksure Technologies.

\* cited by examiner

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#### (57) **ABSTRACT**

Methods and systems for use in indicating and/or determining fuel properties. One or more physical properties of a fuel are determined and indicated using taggants that are added to the fuel, such as by encoding the properties in the taggants or by encoding an identifier in the taggants and associating the properties with the identifier. The taggants are detected by a taggant sensor, and the physical properties are determined based on the detected taggants. A concentration of the taggants in the fuel may also be determined.

**24 Claims, 5 Drawing Sheets**

#### (56) **References Cited**

##### U.S. PATENT DOCUMENTS

5,229,946 A *	7/1993	Ghaem .....	701/106
5,382,942 A *	1/1995	Raffa .....	F01M 11/10
			340/438
5,723,338 A *	3/1998	Rutledge et al. ....	436/56
5,830,763 A *	11/1998	Junk et al. ....	436/56
5,928,954 A *	7/1999	Rutledge et al. ....	436/56
7,811,520 B2	10/2010	Bernhardt	
7,912,653 B1 *	3/2011	Scher et al. ....	702/19

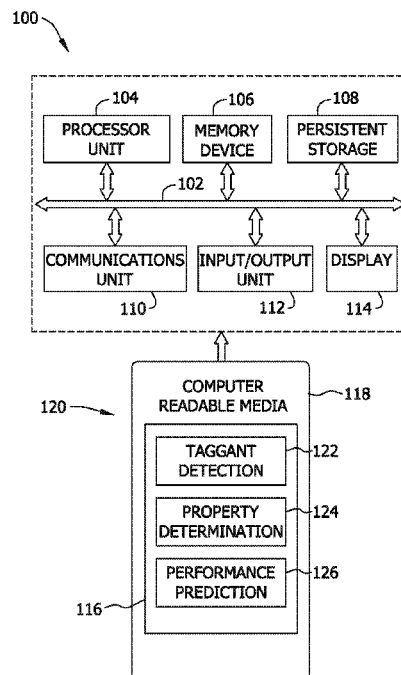


FIG. 1

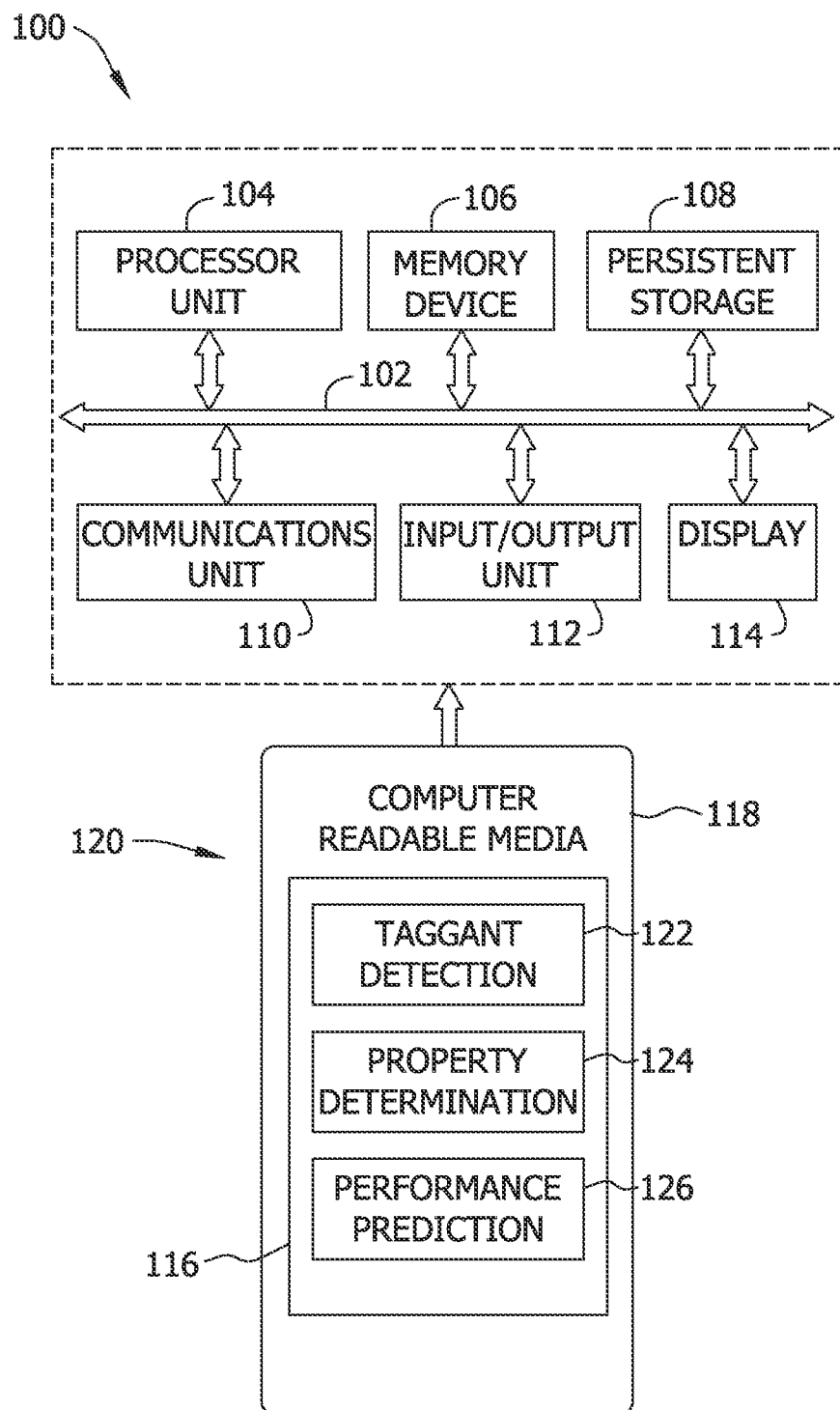


FIG. 2

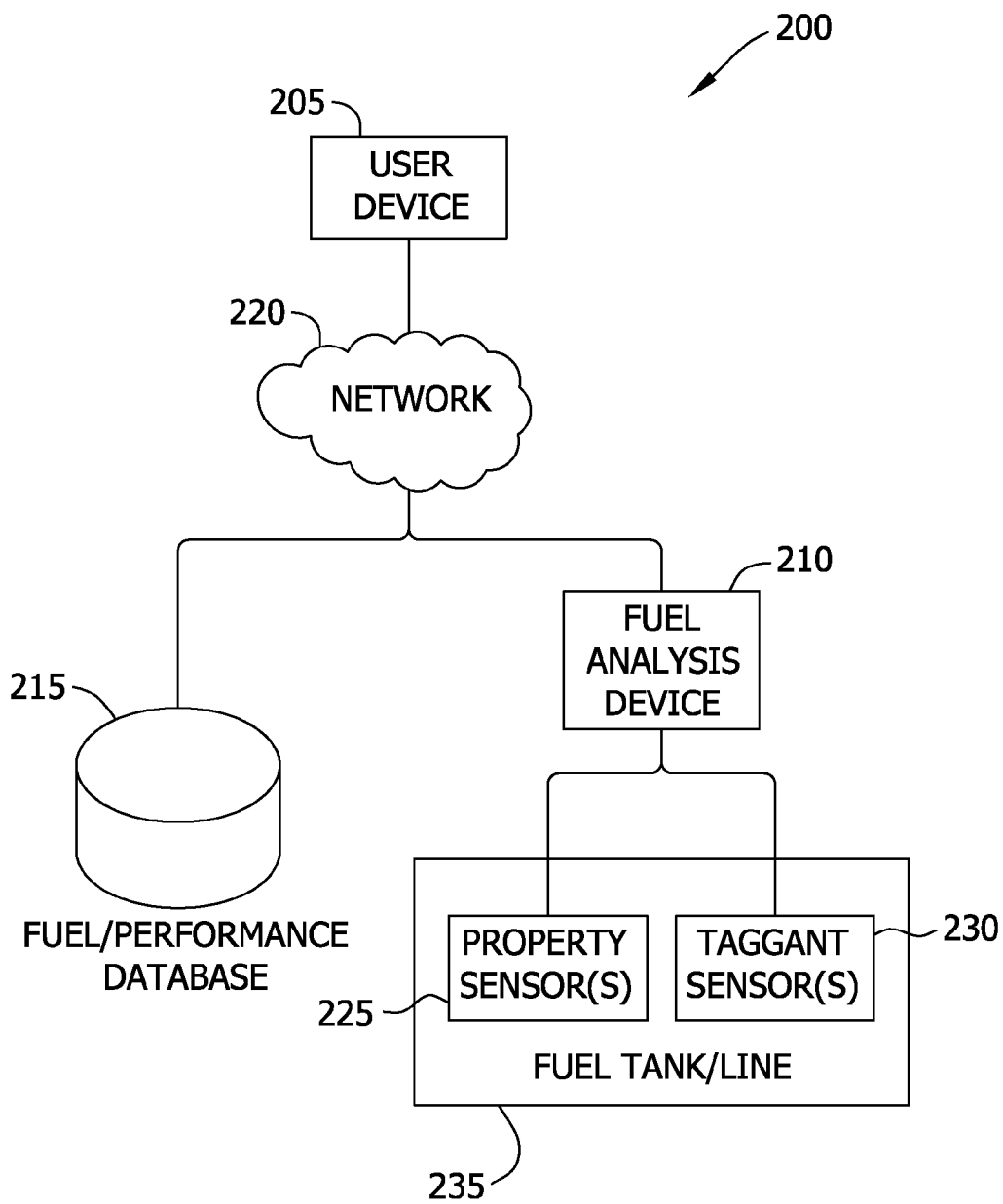


FIG. 3

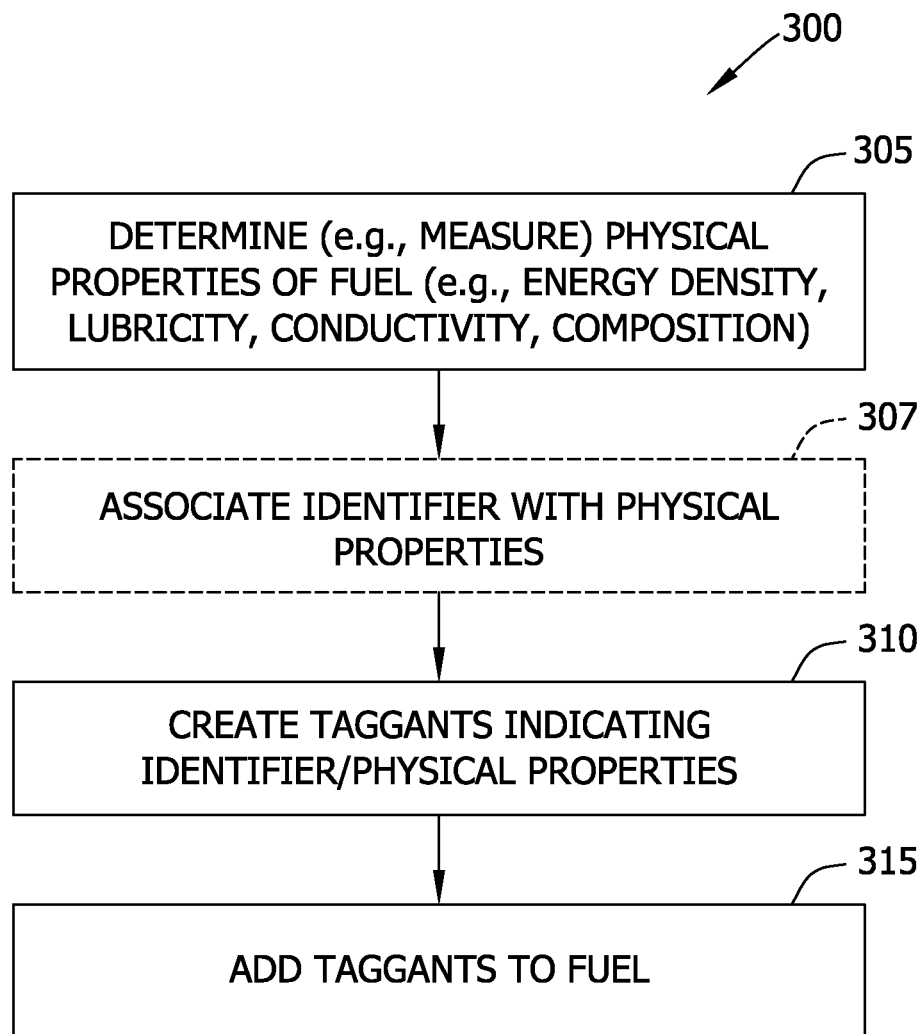


FIG. 4

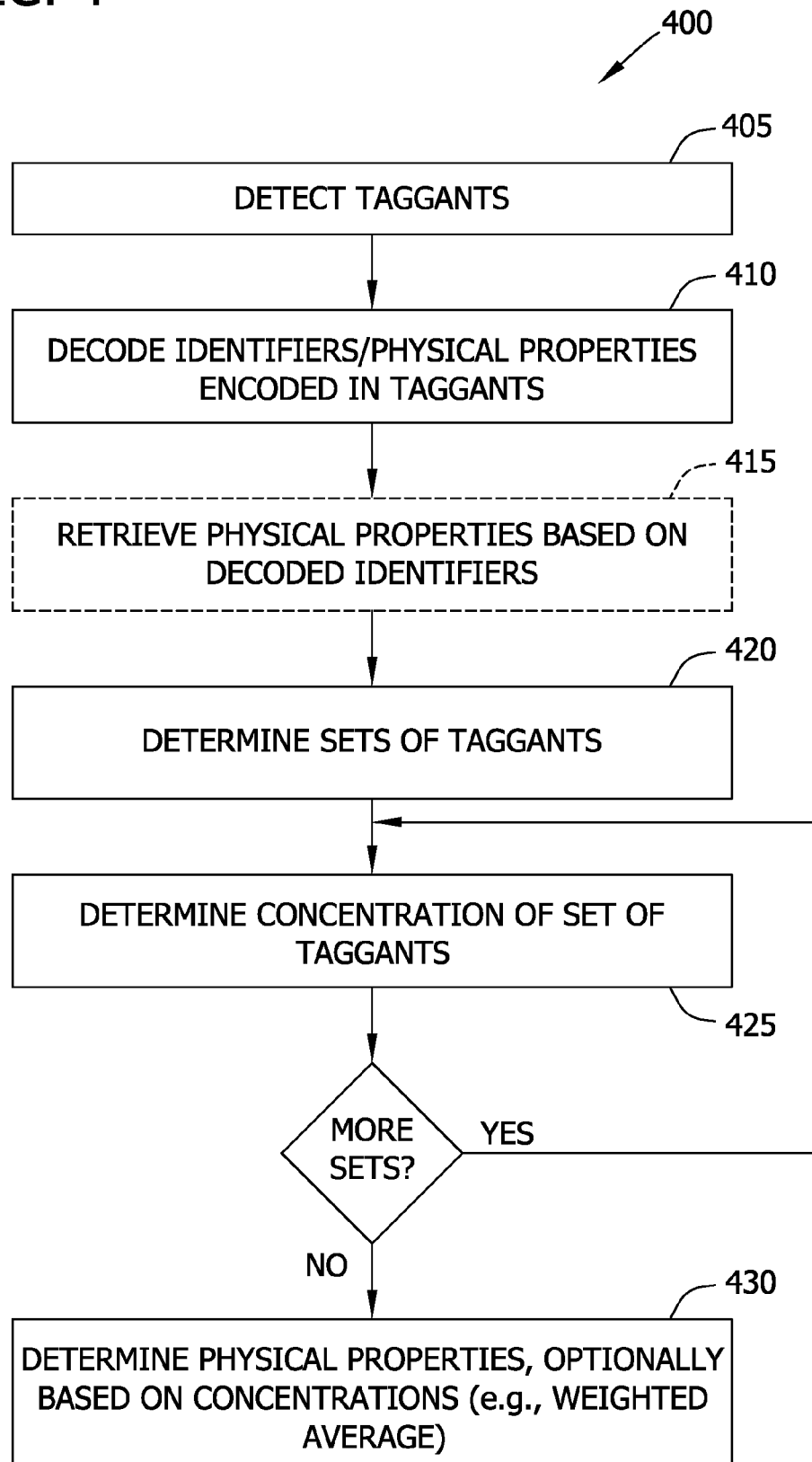
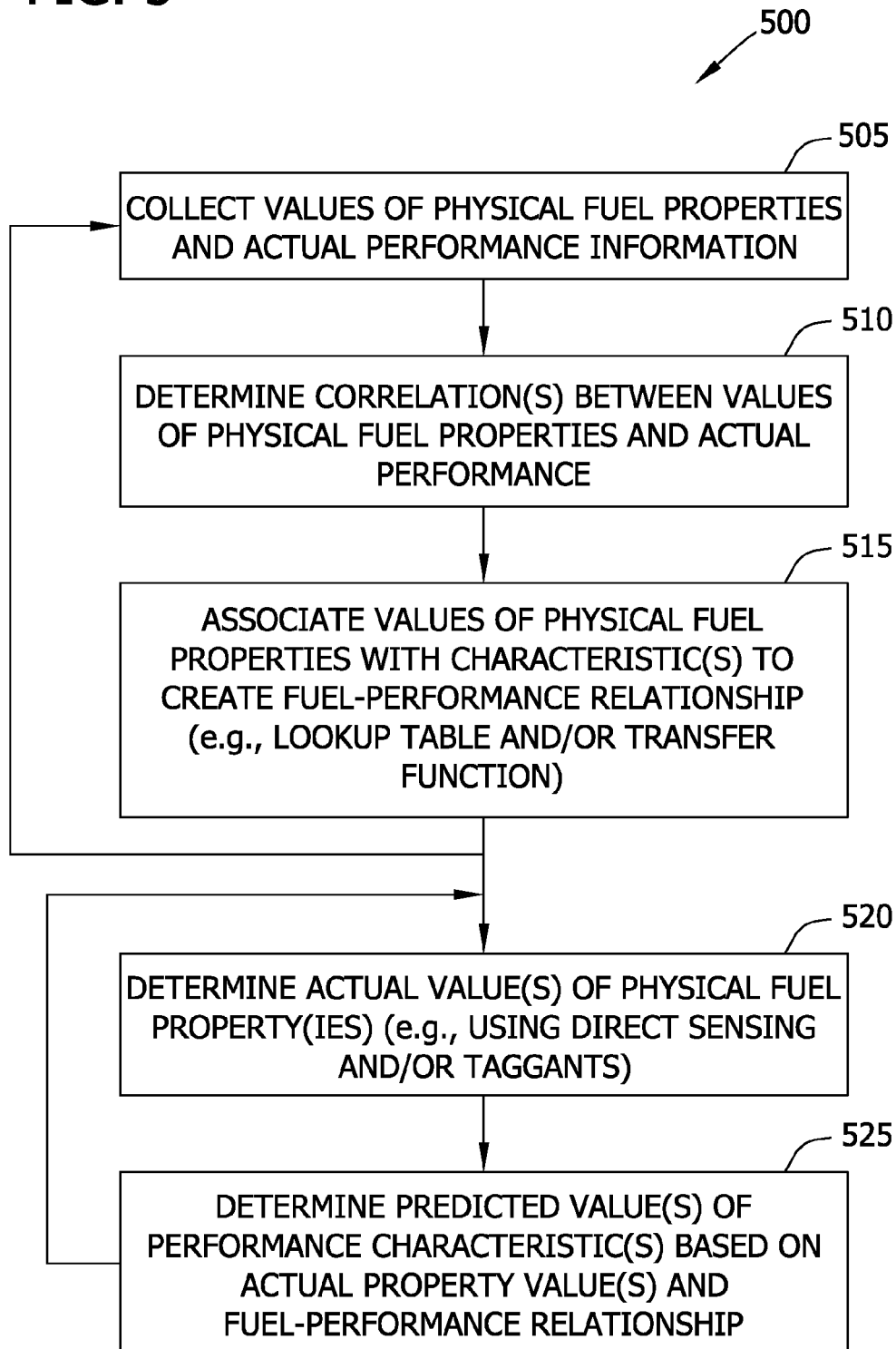


FIG. 5



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## METHODS AND SYSTEMS FOR INDICATING AND DETERMINING FUEL PROPERTIES

### BACKGROUND

The field of the disclosure relates generally to fuel properties and, more specifically, to methods and systems for use in indicating and determining fuel properties using taggants.

Fuels that are used in combustion engines may exhibit different properties, such as energy density, stability, and lubricity. Such varying properties may affect the performance of a combustion engine as well as that of a system (e.g., a vehicle or an electrical generator) that includes a combustion engine. For example, lubricity may affect mechanical wear of engine components, and energy density may affect vehicle range. The properties of the fuel used in a combustion engine may be used to speculate about the performance (e.g., operating and/or maintenance characteristics) of the engine. However, at least some known fuel systems do not allow an operator to reliably determine such properties. Rather, tracking physical fuel properties may require manual record keeping beginning at the point of manufacture and throughout a supply chain.

Moreover, within the supply chain between the fuel manufacturer and the fuel user, fuels may be blended, and contaminants may be introduced. Accordingly, determining fuel properties based on information provided by the manufacturer(s) may be infeasible and/or impossible. As a result, the user may have no reliable source of information for use in predicting system performance.

### BRIEF DESCRIPTION

In one aspect, a method for use in determining one or more fuel properties. The system includes a taggant sensor and a computing device coupled to the taggant sensor. The taggant sensor is configured to detect one or more taggants in a fuel. The computing device is programmed to determine a physical property of the fuel based on the detected taggants, and to determine a concentration of the taggants in the fuel.

In another aspect, a method for use in determining one or more fuel properties is provided. The method includes detecting, by a taggant sensor, one or more taggants in a fuel. A computing device determines a physical property of the fuel based on the detected taggants and also determines a concentration of the taggants in the fuel.

In yet another aspect, a method for use in indicating one or more fuel properties is provided. The method includes determining a physical property of a fuel. An identifier of the fuel is associated with the physical property. A plurality of taggants, each indicating the identifier, is created. The created taggants are added to the fuel.

In still another aspect, one or more non-transitory computer-readable media having computer-executable components embodied thereon are provided. The computer-executable components include a taggant detection component and a property determination component. When executed by at least one processor unit, the taggant detection component causes the processor unit to detect one or more taggants in a fuel. When executed by at least one processor unit, the property determination component causes the processor unit to determine a physical property of the fuel based on the detected taggants, and to determine a concentration of the taggants in the fuel.

The features, functions, and advantages that have been discussed can be achieved independently in various embodi-

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ments or may be combined in yet other embodiments further details of which can be seen with reference to the following description and drawings.

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### BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a block diagram of an exemplary computing device.

FIG. 2 is a block diagram illustrating an exemplary system for use in indicating and/or determining fuel properties.

FIG. 3 is a flowchart of an exemplary method for use in indicating fuel properties using the system shown in FIG. 2.

FIG. 4 is a flowchart of an exemplary method for use in determining fuel properties using the system shown in FIG. 2.

FIG. 5 is a flowchart of an exemplary method for use in determining one or more performance characteristics of a mechanical system that includes a combustion engine using the system shown in FIG. 2.

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### DETAILED DESCRIPTION

Embodiments described herein facilitate indicating and determining one or more physical properties of a fuel to be used with a combustion engine, such that the performance (e.g., operating and/or maintenance characteristics) of the engine and/or of a system including the engine may be predicted. Further, such a determination of physical properties and/or such a prediction of performance may be accomplished when multiple fuels have been blended, and even when multiple blended fuels have been blended into a “blend of blends.”

Physical fuel properties may be directly detected and/or indicated by taggants added to the fuel. As used herein, taggants include chemical and/or physical markers that indicate information, such as an identifier associated with a fuel and/or a physical fuel property. In exemplary embodiments, taggants have a size large enough to enable detection but small enough to avoid negatively affecting the operation of a combustion engine burning the fuel.

Physical properties may be directly detected and/or measured by specialized sensors. For example, a conductivity sensor may measure the conductivity of a fuel. Taggants may be detected using a taggant sensor that corresponds to the form of taggant used. For example, information may be encoded in an optically scannable taggant and subsequently scanned by an optical sensor. As another example, information may be encoded as a chemical signature in a chemical taggant and subsequently detected using a spectroscopic sensor. Such examples are provided for illustrative purposes only, and it is contemplated that the embodiments described herein are operable with any taggants and corresponding sensors.

FIG. 1 is a block diagram of an exemplary computing device 100. In the exemplary embodiment, computing device 100 includes communications fabric 102 that provides communications between a processor unit 104, a memory 106, persistent storage 108, a communications unit 110, an input/output (I/O) unit 112, and a presentation interface, such as a display 114. In addition to, or in alternative to, the presentation interface may include an audio device (not shown) and/or any device capable of conveying information to a user.

Processor unit 104 executes instructions for software that may be loaded into memory 106. Processor unit 104 may be a set of one or more processors or may include multiple processor cores, depending on the particular implementation. Further, processor unit 104 may be implemented using one or more heterogeneous processor systems in which a main pro-

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cessor is present with secondary processors on a single chip. In another embodiment, processor unit **104** may be a homogeneous processor system containing multiple processors of the same type.

Memory **106** and persistent storage **108** are examples of storage devices. As used herein, a storage device is any piece of hardware that is capable of storing information either on a temporary basis and/or a permanent basis. Memory **106** may be, for example, without limitation, a random access memory and/or any other suitable volatile or non-volatile storage device. Persistent storage **108** may take various forms depending on the particular implementation, and persistent storage **108** may contain one or more components or devices. For example, persistent storage **108** may be a hard drive, a flash memory, a rewritable optical disk, a rewritable magnetic tape, and/or some combination of the above. The media used by persistent storage **108** also may be removable. For example, without limitation, a removable hard drive may be used for persistent storage **108**.

A storage device, such as memory **106** and/or persistent storage **108**, may be configured to store data for use with the processes described herein. For example, a storage device may store computer-executable instructions, executable software components (e.g., taggant detection components and/or property determination components), detected taggant information, fuel properties, fuel identifiers, fuel-performance relationships, and/or any other information suitable for use with the methods described herein.

Communications unit **110**, in these examples, provides for communications with other computing devices or systems. In the exemplary embodiment, communications unit **110** is a network interface card. Communications unit **110** may provide communications through the use of either or both physical and wireless communication links.

Input/output unit **112** enables input and output of data with other devices that may be connected to computing device **100**. For example, without limitation, input/output unit **112** may provide a connection for user input through a user input device, such as a keyboard and/or a mouse. Further, input/output unit **112** may send output to a printer. Display **114** provides a mechanism to display information, such as any information described herein, to a user. For example, a presentation interface such as display **114** may display a graphical user interface, such as those described herein.

Instructions for the operating system and applications or programs are located on persistent storage **108**. These instructions may be loaded into memory **106** for execution by processor unit **104**. The processes of the different embodiments may be performed by processor unit **104** using computer implemented instructions and/or computer-executable instructions, which may be located in a memory, such as memory **106**. These instructions are referred to herein as program code (e.g., object code and/or source code) that may be read and executed by a processor in processor unit **104**. The program code in the different embodiments may be embodied on different physical or tangible computer-readable media, such as memory **106** or persistent storage **108**.

Program code **116** is located in a functional form on non-transitory computer-readable media **118** that is selectively removable and may be loaded onto or transferred to computing device **100** for execution by processor unit **104**. Program code **116** and computer-readable media **118** form computer program product **120** in these examples. In one example, computer-readable media **118** may be in a tangible form, such as, for example, an optical or magnetic disc that is inserted or placed into a drive or other device that is part of persistent storage **108** for transfer onto a storage device, such as a hard

drive that is part of persistent storage **108**. In a tangible form, computer-readable media **118** also may take the form of a persistent storage, such as a hard drive, a thumb drive, or a flash memory that is connected to computing device **100**. The tangible form of computer-readable media **118** is also referred to as computer recordable storage media. In some instances, computer-readable media **118** may not be removable.

Alternatively, program code **116** may be transferred to computing device **100** from computer-readable media **118** through a communications link to communications unit **110** and/or through a connection to input/output unit **112**. The communications link and/or the connection may be physical or wireless in the illustrative examples. The computer-readable media also may take the form of non-tangible media, such as communications links or wireless transmissions containing the program code.

In some illustrative embodiments, program code **116** may be downloaded over a network to persistent storage **108** from another computing device or computer system for use within computing device **100**. For instance, program code stored in a computer-readable storage medium in a server computing device may be downloaded over a network from the server to computing device **100**. The computing device providing program code **116** may be a server computer, a workstation, a client computer, or some other device capable of storing and transmitting program code **116**.

Program code **116** may be organized into computer-executable components that are functionally related. For example, program code **116** may include one or more taggant detection components **122**, property determination components **124**, performance prediction components **126**, and/or any component suitable for practicing the methods described herein. Each component may include computer-executable instructions that, when executed by processor unit **104**, cause processor unit **104** to perform one or more of the operations described herein. In exemplary embodiments, taggant detection component **122** causes processor unit **104** to detect one or more taggants in a fuel. Property determination component **124** causes processor unit **104** to determine a value of a physical property of a fuel based on the detected taggants, and to determine a concentration of the taggants in the fuel. Performance prediction component **126** causes processor unit **104** to associate one or more values of a physical property of fuel with a performance characteristic (e.g., an operating characteristic and/or a maintenance characteristic) of a mechanical system to create a fuel-performance relationship, and to determine a predicted value of the performance characteristic based on an actual value of the physical property and the fuel-performance relationship.

The different components illustrated herein for computing device **100** are not meant to provide architectural limitations to the manner in which different embodiments may be implemented. The different illustrative embodiments may be implemented in a computer system including components in addition to or in place of those illustrated for computing device **100**. For example, other components shown in FIG. 1 can be varied from the illustrative examples shown.

As one example, a storage device in computing device **100** is any hardware apparatus that may store data. Memory **106**, persistent storage **108** and computer-readable media **118** are examples of storage devices in a tangible form.

In another example, a bus system may be used to implement communications fabric **102** and may include one or more buses, such as a system bus or an input/output bus. Of course, the bus system may be implemented using any suitable type of architecture that provides for a transfer of data

between different components or devices attached to the bus system. Additionally, a communications unit may include one or more devices used to transmit and receive data, such as a modem or a network adapter. Further, a memory may be, for example, without limitation, memory **106** or a cache such as that found in an interface and memory controller hub that may be present in communications fabric **102**.

FIG. 2 is a block diagram illustrating an exemplary system **200** for use in indicating and/or determining fuel properties. System **200** includes a user device **205**, a fuel analysis device **210**, and a fuel/performance database **215** coupled in communication by a network **220**. In exemplary embodiments, each of user device **205**, fuel analysis device **210**, and fuel/performance database **215** is an instance of a computing device **100**. Network **220** may include, for example, a local area network (LAN), a wireless LAN, a wide area network (WAN), a mobile telecommunications network, and/or the Internet.

Fuel analysis device **210** is coupled to one or more property sensors **225** and/or one or more taggant sensors **230**, which are positioned at least partially within a fuel tank and/or line **235**. For example, fuel analysis device **210** may be positioned in a fuel production and/or distribution facility, in which case property sensors **225** and/or taggant sensors **230** may be positioned at least partially within a fuel tank **235** of a fueling system at the facility. As another example, fuel analysis device **210** may be positioned onboard a vehicle, in which case property sensors **225** and/or taggant sensors **230** may be positioned at least partially within a fuel tank and/or fuel line **235** of the vehicle.

Property sensors **225** are configured to directly detect and/or measure one or more physical properties of fuel within fuel tank and/or line **235**, and to transmit a signal indicating the physical fuel property(ies) to fuel analysis device **210**. Taggant sensors **230** are configured to detect information indicated by taggants within the fuel, and to transmit a signal indicating such information to fuel analysis device **210**.

In exemplary embodiments, a property sensor **225** is a sensor configured to directly detect and/or measure a physical property of the fuel. As an example, a conductivity sensor may include two electrodes that extend into fuel contained within fuel tank and/or line **235**, and a measuring device for measuring the conductance between the two electrodes. Such a conductivity sensor may be configured to produce a signal indicating the measured conductance. Similarly, property sensors **225** may include any sensor that is operable to detect a physical property of a fuel within fuel tank and/or line **235**.

A taggant sensor **230** is a device configured to detect the presence of one or more taggants (e.g., chemical and/or physical markers) within the fuel contained in fuel tank and/or line **235**. Taggant sensor **230** corresponds to the form of taggant used. For example, an optical taggant sensor **230** may be used to detect optically scannable taggants, whereas a spectroscopic taggant sensor **230** may be used to detect chemical taggants.

FIG. 3 is a flowchart of an exemplary method **300** for use in indicating fuel properties using system **200** (shown in FIG. 2). Referring to FIGS. 2 and 3, in exemplary embodiments, one or more physical properties of a fuel are determined **305**. The physical properties may include, for example, fuel type (e.g., gasoline, ethanol, and/or diesel), composition (e.g., ingredients), energy density, stability, lubricity, acidity, heat capacity, viscosity, conductivity, and/or dielectric constant. Physical fuel properties may be determined **305** in a variety of ways, such as by directly measuring the properties and/or by predicting the properties based on the production process and/or ingredients used to create the fuel. For example, a

particular fuel formulation may be known (e.g., based on past measurement and/or experimentation) to result in a particular energy density.

Taggants enabling the subsequent determination of the physical fuel property(ies) are created **310**. In exemplary embodiments, a computing device **100** (shown in FIG. 1), such as user device **205** and/or fuel analysis device **210**, associated **307** an identifier of the fuel (e.g., a batch number and/or other serial number) with the physical fuel properties that have been determined **305**. For example, the identifier and the properties may be associated **307** by storing the identifier and properties in association in fuel/performance database **215**. In such embodiments, the taggants created **310** indicate the identifier of the fuel. For example, the fuel identifier may be encoded in the taggants.

In other embodiments, rather than linking physical fuel properties to an identifier, taggants indicating the physical fuel properties themselves are created **310**. For example, the physical fuel properties may be encoded in the taggants.

The taggants are added **315** to the fuel. In exemplary embodiments, taggants are added **315** to the fuel substantially at (e.g., within 1%, 2%, or 5% of) a predetermined concentration. Adding the taggants at a known concentration facilitates subsequently determining the amount (e.g., concentration) of a particular fuel in a fuel tank and/or line **235** when multiple fuels are blended together.

FIG. 4 is a flowchart of an exemplary method for use in determining fuel properties using system **200** (shown in FIG. 2). Referring to FIGS. 2 and 4, fuel analysis device **210** detects **405** one or more taggants in the fuel within fuel tank and/or line **235**, such as by receiving signals from taggant sensors **230**. As described above, the taggants indicate one or more fuel identifiers and/or physical fuel properties.

Fuel analysis device **210** decodes **410** information encoded in the taggants and determines **430** one or more physical properties of the fuel based on the decoded information. In exemplary embodiments, fuel analysis device **210** determines **430** physical fuel properties at least in part by decoding **410** an identifier encoded in the taggants and retrieving **415** a physical fuel property from fuel/performance database **215** based on the decoded identifier. For example, fuel analysis device **210** may retrieve from fuel/performance database all physical properties that are associated with the fuel identifier. In addition, or alternatively, physical fuel properties may be directly encoded in taggants, and fuel analysis device **210** may determine **430** physical fuel properties at least in part by decoding **410** a physical property encoded in a taggant. Accordingly, the physical properties of the fuel in a fuel tank and/or line **235** may be determined **430** based directly on the content of the fuel itself and without reliance on inconvenient and error-prone manual record keeping.

In exemplary embodiments, method **400** facilitates determining **430** fuel properties even when multiple fuels have been blended together. For example, the fuel may include a blend of a first batch of fuel and a second batch of fuel. In such embodiments, fuel analysis device **210** determines **420** how many sets of taggants are present in the fuel. For example, in decoding **410** information encoded in the taggants, fuel analysis device **210** may identify a first set of taggants associated with the first batch of fuel (e.g., indicating a first fuel identifier and/or a first value of a physical fuel property) and a second set of taggants associated with the second batch of fuel (e.g., indicating a second fuel identifier and/or a second value of the same physical fuel property).

Fuel analysis device **210** determines **425** the concentration of each set of taggants in the fuel. For example, fuel analysis device **210** may determine **425** a first concentration of the first

set of taggants and a second concentration of the second set of taggants. In exemplary embodiments, the concentration of each set of taggants is equal to the quantity of taggants in the set divided by the total quantity of taggants detected **405**. For example, if the first set includes 1000 taggants, and the second set includes 2000 taggants, the concentration of the first set is equal to  $\frac{1}{3}$  (1000 divided by 3000), and the concentration of the second set is equal to  $\frac{2}{3}$  (2000 divided by 3000). Alternatively, the concentration of each set of taggants may be equal to the quantity of taggants in the set divided by the expected total quantity of taggants for the volume of fuel in fuel tank and/or line **235**. For example, if taggants are added **315** (shown in FIG. 3) to fuels at a predetermined concentration, an expected total quantity of taggants for a volume of fuel may be calculated by multiplying the volume by the predetermined concentration.

When fuel analysis device **210** has determined **425** the concentration of each set of taggants, fuel analysis device **210** determines **430** one or more physical properties of the fuel based at least in part on the concentrations. In exemplary embodiments, fuel analysis device **210** has decoded **410** and/or retrieved **415** numeric values of physical properties corresponding to each set of taggants, as described above. In such embodiments, fuel analysis device **210** may determine **430** the physical properties of the fuel by calculating a weighted average of the decoded/retrieved values, with the values weighted based on the corresponding concentrations. For example, a first value of conductivity (e.g., expressed in siemens per meter) associated with the first set of taggants and a second value of conductivity associated with the second set of taggants may be combined by weighting the first value based on the concentration of the first set of taggants and weighting the second value based on the concentration of the second set of taggants.

Accordingly, exemplary embodiments enable the determination of physical properties of fuel blends and even blends of blends. Such properties are determined in a manner that reflects the proportion of each component fuel in the blend.

In addition to indicating physical fuel properties, embodiments provided herein further facilitate predicting performance of a system in which a fuel is to be combusted. FIG. 5 is a flowchart of an exemplary method **500** for use in determining one or more performance characteristics of a mechanical system that includes a combustion engine using system **200** (shown in FIG. 2).

In exemplary embodiments, values of physical fuel properties and corresponding actual performance information are collected **505** over time. For example, a subset of a fleet of vehicles may be treated as an experimental group for testing a particular fuel. The same fuel may be provided to all vehicles in the experimental group, and resulting performance information may be collected **505**. As another example, a fuel may be evaluated in a lab for materials compatibility with one or more components (e.g., a fuel line seal) within a combustion engine and/or mechanical system.

As described herein, collected physical fuel properties may include, without limitation, fuel type (e.g., gasoline, ethanol, and/or diesel), composition (e.g., ingredients), energy density, stability, lubricity, acidity, heat capacity, viscosity, conductivity, and/or dielectric constant. Performance information includes maintenance information and/or operating information. For example, maintenance information may include, without limitation, a system condition at specific times, component replacement events, mechanical wear of one or more components (e.g., per unit of fuel and/or time of exposure), and/or deterioration of one or more components (e.g., per unit of fuel and/or time of exposure). Operating

information may include, without limitation, an operating speed (e.g., a maximum operating speed of an engine or mechanical system), an operating range (e.g., with respect to distance and/or meteorological conditions, such as temperature), an engine output per unit of fuel, and/or a mechanical system output per unit of fuel.

In exemplary embodiments, because the relationship between fuel properties and performance characteristics may be unpredictable prior to performing method **500**, fuel properties and performance information may be over-collected. For example, a relatively large quantity of factors may be sampled, and these factors may be sampled relatively frequently.

Correlations are determined **510** between the values of physical fuel properties and actual performance. For example, determining **510** correlations may include applying regression analysis and/or other statistical methods to the fuel and performance data previously collected **505**.

In exemplary embodiments, one or more values of one or more physical fuel properties (e.g., an energy density of the fuel, a stability of the fuel, a lubricity of the fuel, an acidity of the fuel, and/or a heat capacity of the fuel) are associated **515** with a performance characteristic (e.g., an operating characteristic and/or a maintenance characteristic) of a mechanical system based on the determined correlations to create a fuel-performance relationship. For example, fuel-performance relationships may be created for factors demonstrating marked correlation (e.g., a correlation coefficient greater than 0.6) or high correlation (e.g., a correlation coefficient greater than 0.8). As described above, maintenance characteristics include, but are not limited to, mechanical wear per unit of fuel and/or deterioration per unit of fuel. Operating characteristics include, but are not limited to, an operating speed, an operating range, an engine output per unit of fuel, and/or a mechanical system output per unit of fuel.

In some embodiments, creating a fuel-performance relationship includes creating a lookup table that associates a plurality of values of one or more physical properties of fuel with a plurality of values of one or more performance characteristics of the mechanical system. In other embodiments, creating a fuel-performance relationship includes defining a transfer function that relates one or more physical properties of fuel to the performance characteristic of the mechanical system. Fuel-performance relationships may be stored in fuel/performance database **215** and/or distributed to fuel analysis devices **210**.

In exemplary embodiments, the collection **505**, determination **510**, and association **515** described above are performed repeatedly, such that fuel-performance relationships may be refined over time. For example, such repetition may produce a larger data set from which correlations may be determined **510**.

In operation, fuel analysis device **210** determines **520**, using property sensors **225** and/or taggant sensors **230**, an actual value of one or more physical properties of fuel to be burned by a combustion engine (e.g., fuel within fuel tank and/or line **235**). As described above, values of physical fuel properties may be determined **520** based on taggants by decoding **410** (shown in FIG. 4) the physical properties directly from the taggants and/or by decoding **410** a fuel identifier and retrieving **415** (shown in FIG. 4) the physical fuel properties from fuel/performance database **215**.

Fuel analysis device **210** determines **525** a predicted value of the performance characteristic based on the actual value of the physical property(ies) and the fuel-performance relationship. For example, if the fuel-performance relationship is a lookup table, fuel analysis device **210** determines **525** the

predicted value by selecting a value of the performance characteristic from the lookup table based on the actual value(s) of the physical property(ies). If a determined actual value does not appear in the lookup table, fuel analysis device 210 may select the value of the performance characteristic corresponding to a reference value of the physical property that most closely matches the determined actual value. Alternatively, if the determined actual value is between two reference values in the lookup table, fuel analysis device 210 may calculate an average of the values of the performance characteristic corresponding to the two reference values. If the fuel-performance relationship is a transfer function, fuel analysis device 210 may determine 525 the predicted value of the performance characteristic by calculating the value of the performance characteristic based on the transfer function and the actual value of the physical property(ies).

Accordingly, predictions of future performance may be made based on past observed performance and detected fuel properties. Further, such predictions may be repeated over time, and refinement of the fuel-performance relationship enables such predictions to improve in accuracy.

This written description uses examples to disclose various embodiments, which include the best mode, to enable any person skilled in the art to practice those embodiments, including making and using any devices or systems and performing any incorporated methods. The patentable scope is defined by the claims, and may include other examples that occur to those skilled in the art. Such other examples are intended to be within the scope of the claims if they have structural elements that do not differ from the literal language of the claims, or if they include equivalent structural elements with insubstantial differences from the literal languages of the claims.

What is claimed is:

1. A system for use in determining one or more fuel properties, said system comprising:

a taggant sensor configured to detect a plurality of taggants in a blend of fuel that includes a first batch of fuel and a second batch of fuel; and

a computing device coupled to said taggant sensor and programmed to:

determine a physical property of the blend of fuel based on (i) information encoded in the plurality of taggants and (ii) determining a first concentration of a first set of the plurality of taggants associated with the first batch of fuel and a second concentration of a second set of the plurality of taggants associated with the second batch of fuel; and

predict a performance, including estimated maintenance data, of an engine using the blend of fuel, based on the determined physical property and mechanical wear of one or more components; and

wherein a user performs a maintenance event based on the predicted performance.

2. A system in accordance with claim 1, wherein said computing device is programmed to predict at least one of a system condition at specific times, component replacement events, and deterioration of the one or more components per unit of the blend of fuel.

3. A system in accordance with claim 1, wherein said computing device is programmed to determine the physical property of the blend of fuel at least in part by decoding the physical property encoded in the plurality of taggants.

4. A system in accordance with claim 1, wherein said computing device is further programmed to determine an energy density of the blend of fuel, a stability of the blend of

fuel, a lubricity of the blend of fuel, an acidity of the blend of fuel, or a heat capacity of the blend of fuel.

5. A system in accordance with claim 1, wherein said computing device is further programmed to determine a dielectric constant of the blend of fuel or a conductivity of the blend of fuel.

6. A system in accordance with claim 1, wherein said computing device is further programmed to determine the physical property of the blend of fuel based at least in part on the first concentration and the second concentration.

7. A system in accordance with claim 1, wherein said taggant sensor is an optical sensor.

8. A method for use in determining one or more fuel properties, said method comprising:

detecting, by a taggant sensor, a plurality of taggants in a blend of fuel that includes a first batch of fuel and a second batch of fuel;

determining, by a computing device, a physical property of the blend of fuel based on (i) information encoded in the plurality of taggants and (ii) determining a first concentration of a first set of the plurality of taggants associated with the first batch of fuel and a second concentration of a second set of the plurality of taggants associated with the second batch of fuel;

predicting a performance, including estimated maintenance data, of an engine using the blend of fuel, based on the determined physical property and mechanical wear of one or more components; and

performing a maintenance event based on the predicted performance.

9. A method in accordance with claim 8, wherein determining a physical property of the blend of fuel comprises: decoding identifiers encoded in the plurality of taggants; and

retrieving the physical property from a database based on the decoded identifiers.

10. A method in accordance with claim 8, wherein determining the physical property of the blend of fuel comprises determining: an energy density of the blend of fuel, a stability of the blend of fuel, a lubricity of the blend of fuel, an acidity of the blend of fuel, or a heat capacity of the blend of fuel.

11. A method in accordance with claim 8, wherein determining the physical property of the blend of fuel comprises determining: a dielectric constant of the blend of fuel or a conductivity of the blend of fuel.

12. A method in accordance with claim 8, wherein determining the physical property of the blend of fuel comprises determining: a fuel type of the blend of fuel or a composition of the blend of fuel.

13. A method in accordance with claim 8, wherein determining the physical property of the blend of fuel further comprises decoding the physical property encoded in the plurality of taggants.

14. A method in accordance with claim 8, further comprising determining the physical property of the blend of fuel based at least in part on the first concentration and the second concentration.

15. A method in accordance with claim 14, wherein determining the physical property of the blend of fuel based at least in part on the first concentration and the second concentration comprises calculating a weighted average of a first value associated with the first set of the plurality of taggants and a second value associated with the second set of the plurality of taggants, wherein a weight of the first value corresponds to the first concentration, and a weight of the second value corresponds to the second concentration.

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**16.** A method for use in indicating one or more fuel properties, said method comprising:

determining a first value of a physical property of a first batch of fuel and a second value of the physical property of a second batch of fuel;

associating, by a computing device, a first identifier of the first batch of fuel with the first value of the physical property and a second identifier of the second batch of fuel with the second value of the physical property;

creating a first plurality of taggants, wherein the first plurality of taggants encode information that indicates the first identifier and creating a second plurality of taggants, wherein the second plurality of taggants encode information that indicates the second identifier;

adding the first plurality of taggants to the first batch of fuel and adding the second plurality of taggants to the second batch of fuel;

combining the first batch of fuel and the second batch of fuel into a blend of fuel such that a first concentration of the first plurality of taggants associated with the first batch of fuel and a second concentration of the second plurality of taggants associated with the second batch of fuel indicate a combined value of the physical property in the blend of fuel;

predicting a performance, including estimated maintenance data, of an engine using the blend of fuel, based on the first value of the physical property, the second value of the physical property, and mechanical wear of one or more components; and

performing a maintenance event based on the predicted performance.

**17.** A method in accordance with claim **16**, wherein adding the taggants to the first batch of fuel comprises adding the plurality of taggants to the first batch of fuel within 5% of a predetermined concentration.

**18.** A method in accordance with claim **16**, wherein associating the first identifier with the physical property comprises associating the first identifier with: an energy density of the first batch of fuel, a stability of the first batch of fuel, a lubricity of the first batch of fuel, an acidity of the first batch of fuel, or a heat capacity of the first batch of fuel.

**19.** A method in accordance with claim **16**, wherein associating the first identifier with the physical property comprises associating the first identifier with: a dielectric constant of the first batch of fuel or a conductivity of the first batch of fuel.

**20.** A method in accordance with claim **16**, wherein associating the first identifier with the physical property com-

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prises associating the first identifier with: a fuel type of the first batch of fuel or a composition of the first batch of fuel.

**21.** One or more non-transitory computer-readable media having computer-executable components embodied thereon, said computer-executable components comprising:

a taggant detection component that when executed by at least one processor unit causes the processor unit to detect a plurality of taggants in a blend of fuel that includes a first batch of fuel and a second batch of fuel; and

a property determination component that when executed by at least one processor unit causes the processor unit to:

determine a physical property of the blend of fuel based on (i) information encoded in the plurality of taggants and (ii) determining a first concentration of a first set of the plurality of taggants associated with the first batch of fuel and a second concentration of a second set of the plurality of taggants associated with the second batch of fuel; and

predict a performance, including estimated maintenance data, of an engine using the blend of fuel, based on the determined physical property and mechanical wear of one or more components; and

wherein a user performs a maintenance event based on the predicted performance.

**22.** One or more non-transitory computer-readable media in accordance with claim **21**, wherein said property determination component causes the processor to determine a physical property of the blend of fuel at least in part by:

decoding identifiers encoded in the plurality of taggants; and

retrieving the physical property from a database based on the decoded identifiers.

**23.** One or more non-transitory computer-readable media in accordance with claim **21**, wherein said property determination component causes the processor to determine the physical property of the blend of fuel at least in part by decoding the physical property encoded in the plurality of taggants.

**24.** One or more non-transitory computer-readable media in accordance with claim **21**, wherein said property determination component further causes the processor to:

determine an energy density of the blend of fuel, a stability of the blend of fuel, a lubricity of the blend of fuel, an acidity of the blend of fuel, or a heat capacity of the blend of fuel.

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